

200 Market Street, Portland December Data Acquisition Report



The background of the entire page is a faded, artistic image of several interlocking metal gears. The gears are of various sizes and are arranged in a way that creates a sense of mechanical complexity. The colors are muted, with shades of grey, brown, and a hint of yellow, giving it a technical and industrial feel.

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Introduction:

This report is intended to present the initial test data for technical review and assessment with the intention that instrumentation be checked for accuracy where data suggest.

Site Description:


Design has been completed of a 30-kilowatt Capstone Microturbine to generate electricity for emergency/night lighting circuits for the entire office facility located at 200 SW Market St. Portland, Oregon. The electrical output is being utilized 8,760 hours per year. All available waste heat from the natural gas turbine is being reclaimed through a Unifin Micogen model exhaust-to-water heat exchanger. All the hot water generated from waste heat reclaim is being used either directly for space heating or to generate chilled water through a Yazaki, indirect-direct fired, absorption chiller. The project has been instrumented with an Opto22 control system that is capable of providing live streaming data to a web site for all to view.

The electric output of the Capstone is estimated to be 27 KW and will be fed through an automatic transfer switch to a new sub-panel for night lighting/egress lighting, PNL-4EL. Night lighting was chosen because it represents a 24/7 100% load factor and a load that is fairly linear. Electronic ballasts may affect the power factor and final load will be adjusted accordingly to maximize the net output of the turbine. Under turbine curtailment of any kind, load will be automatically transferred to the utility. All egress fixtures have battery backup so no interruption to egress function is anticipated.

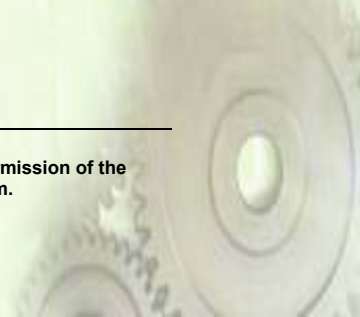
Exhaust gas from the turbine will be ducted to a Unifin heat exchanger, manufactured by Koch Industries of Canada, designed to produce 190 °F hot water at 40 gpm. A diverting damper in the Unifin will automatically send turbine combustion products to either the heat exchanger (HX) or to the atmosphere depending on operating requirements. Final products of combustion will contain less than 9 ppm NOX.

The hot water will be either used to pre-heat boiler feed water or to produce chilled water through an absorption chiller. The energy management system, has logged runtimes on the boiler system for the past 5 years and averages indicate 25% runtime. This percentage was used in the calculations to show decreased boiler load. It is important to note that the heat reclaimed is significantly lower than the boiler plant capacity at approximately 180 MBH. The remaining 75% of the time, the hot water will be diverted through an automatically controlled 3-way valve to a direct, water-fired absorption chiller. The absorption unit selected is a Yazaki 10 ton-refrigeration chiller.

Figure one present the front of the office building with the new Cooling, Heating and Power (CHP) demonstration building located on the ground floor on the left side facing the front of the building. This new building addition blends into the "green" nature of the building with a three foot deep earth roof. The prominent picture window was constructed to allow the public to view the CHP systems as well as the computer monitoring system.



A website has always been a window on the past, a very intuitive machine.



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Figure 2 Microturbine, Heat Recovery Heat Exchanger and Absorption Chiller

Figure two presents the nominal 30 kW Capstone microturbine (left), a Unifin heat recovery heat exchanger (center) and finally a Yazaki nominal 10 refrigeration ton (RT) (right). The insulated exhaust duct work delivers the microturbine exhaust to the Unifin heat exchanger (top left foreground) and the flue gas exhaust leaving the Unifin (background right). Figure three presents the opposite view of the CHP facility where the back of the control station is seen on the left.

Microturbine

The microturbine ran intermittently throughout the summer period as summarized in Table 1 and Table 2. Data collection was also intermittent. Some performance data were captured from July 18 through September 11. The data were not collected from September 11 through October 21. Data collection has been occurring consistently since October 21, though we are typically collecting about one 10-minute record per hour (or about 1 out of every 6 possible records). As a result, the total energy use data in Table 2 are not necessarily representative of the month. The cumulative operating hours provide the best indication of turbine activity for the month. The parasitic power is about 10% of the total output as expected. The average net efficiency based on higher heating value is about 20-22%.

System Efficiency

Cooling, heating and power (CHP) system fuel efficiency is the key energy measure for this project. This efficiency measure is determined by the formula:

$$\left[(\text{electric output MBtu/h}) + (\text{thermal output MBtu/h}) \right] \div \text{gas input MBtu/h}$$

The microturbine and absorption chiller performance used in the calculation are rated data points as more data will be necessary to plot final performance.

Data collection has been occurring consistently since October 21, though the project has typically been collecting about one 10-minute record per hour (or about 1 out of every 6 possible records). For December the data collection rate increased to about one quarter of the possible records. As a result, the total energy use data in Table 2 are not necessarily representative of the month. The cumulative

operating hours provide the best indication of turbine activity for the month. The parasitic power is about 10% of the total output as expected. The average net efficiency based on higher heating value is about 20-22%.

Table 1. Data Periods

July 18, 2002	First Data Collected
Aug 2, 2002	Capstone output changed from 27 kW to 25 kW
Sep 11, 2002	Last Recorded Chiller Activity for Cooling Season
Sep 11 – Oct 21, 2002	Data not collected or lost
Oct 21, 2002	Intermittent Data Collection begins again
Dec 16, 2002	Hot water and chilled water flow sensors suddenly failed

Table 2. Monthly Summary of Energy and Runtime Data

Month	Percent Valid Data (%)	Logged Turbine Operating Hours	Total System Power (kWh)	Net Power Output (kWh)	Parasitic Power (kWh)	Gas Use (therms)	Avg Efficiency (% HHV)	Recovered Heat (MMBtu)
Jul-02	11.8	83	955	852	103.3	138.1	21.0%	0.7
Aug-02	52.7	143	2,218	2,048	206.7	336.4	20.8%	16.1
Sep-02	9.1	55	720	663	69.9	102.7	22.0%	4.8
Oct-02	7.9	360	1,605	1,486	146.5	230.8	22.0%	10.6
Nov-02	18.3	700	3,591	3,322	307.1	511.9	22.1%	23.1
Dec-02	24.4	695	4,914	4,508	436.9	685.1	22.5%	17.7

Table 3 attempts to estimate monthly energy use using the cumulative logged turbine hours from Table 2. In December, the logged turbine runtime was 695 hours, which are just a few hours short of the 744 possible hours in December. The collected data records also indicated that the turbine was never down for the month. Therefore, we assume that the turbine ran continuously and the electric production and gas use are estimated by proportionally scaling the collected data for the month.

The drop in the thermal efficiency for December (Table 4) was due to an instrumentation problem with the hot water flow meter that is discussed below. In reality, it seems likely that the heat recovery performance in December remained similar to previous months.

Table 3. Monthly Estimated Energy

Month	Total Monthly Hours	Estimated Total System Power (kWh)	Estimated Net Power Output (kWh)	Estimated Parasitic Power (kWh)	Estimated Gas Use (therms)	Estimated Heat Recovery (MMBtu)
Nov-02	720	19,623	18,151	1,678	2,797	126.4
Dec-02	744	20,141	18,475	1,791	2,808	72.6

Table 4. CHP System Performance

Month	Power + thermal out		
	Microturbine Avg Efficiency (% HHV)	Useful Output in HEATING Mode: E+Qh (MMBtu)	Overall "CHP" Efficiency in HEATING Mode
Nov-02	22.1%	188.4	67.3%
Dec-02	22.5%	135.7	48.3%

December General Data

The shade plot in Figure 3 shows when the data are missing (white areas) as well as when the turbine ran (darker areas). None of the data collected ever indicated that the turbine was off in December.

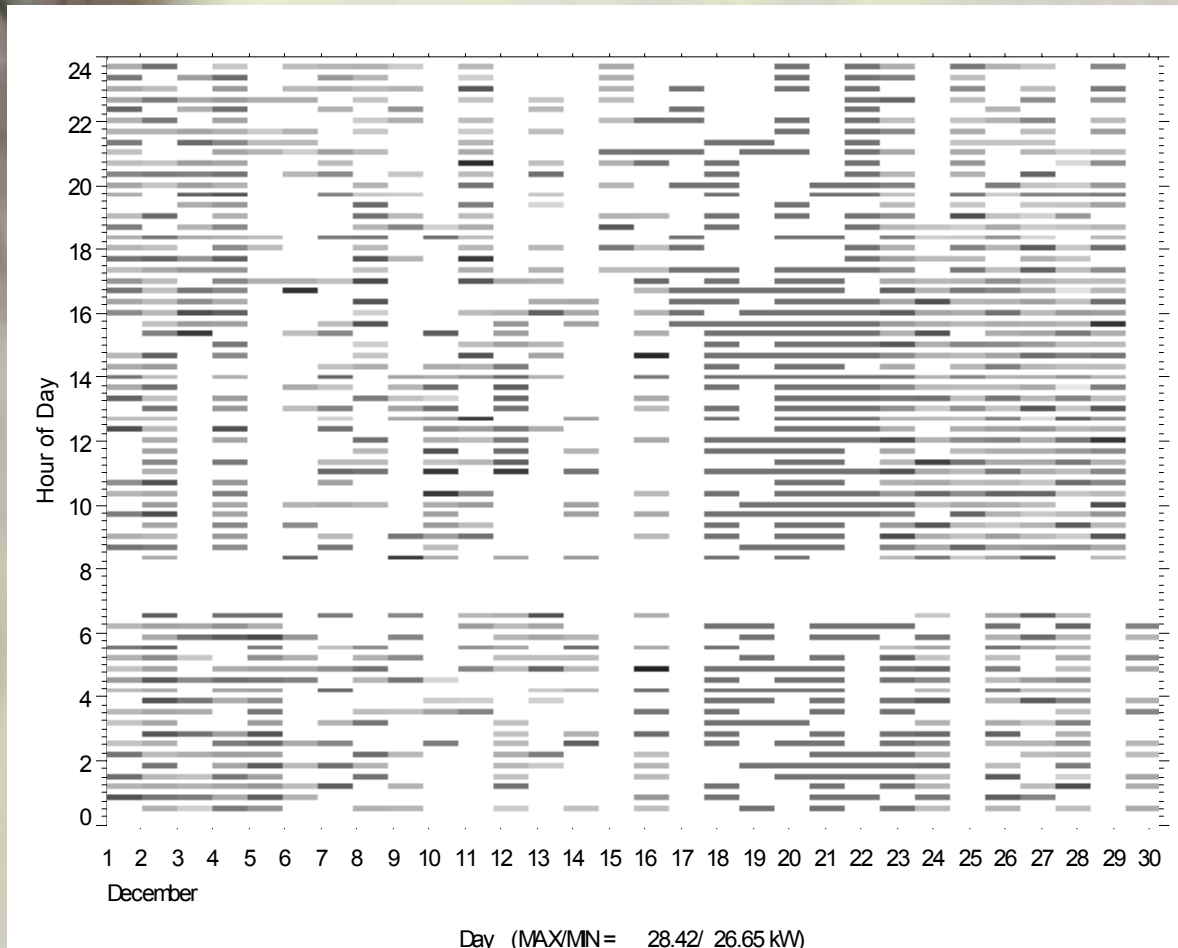


Figure 3. Shade Plot of Turbine Power Output

Turbine Performance

The following plots (Figure 4 through 6) compare the measured performance of the Capstone 30 to the expected trend. The data shown as *black diamonds* are for the periods before August 2, 2002, when the turbine had been set to produce its rated output of 27 kW. After August 2, the turbine output setting dropped to 25 kW. These data are shown as *green **s. The blue lines on the graphs are the expected performance trends with ambient temperature from the published Capstone specifications (converted to higher heating values).

Both the power and efficiency are higher than expected at the high "inlet" temperatures recorded in the mechanical room by the Capstone SCADA system. Though the results may imply that the temperature sensor is somehow skewed. If the data in all three plots were shifted to the left by 40-45°F, the measured data would be more in line with expectations.

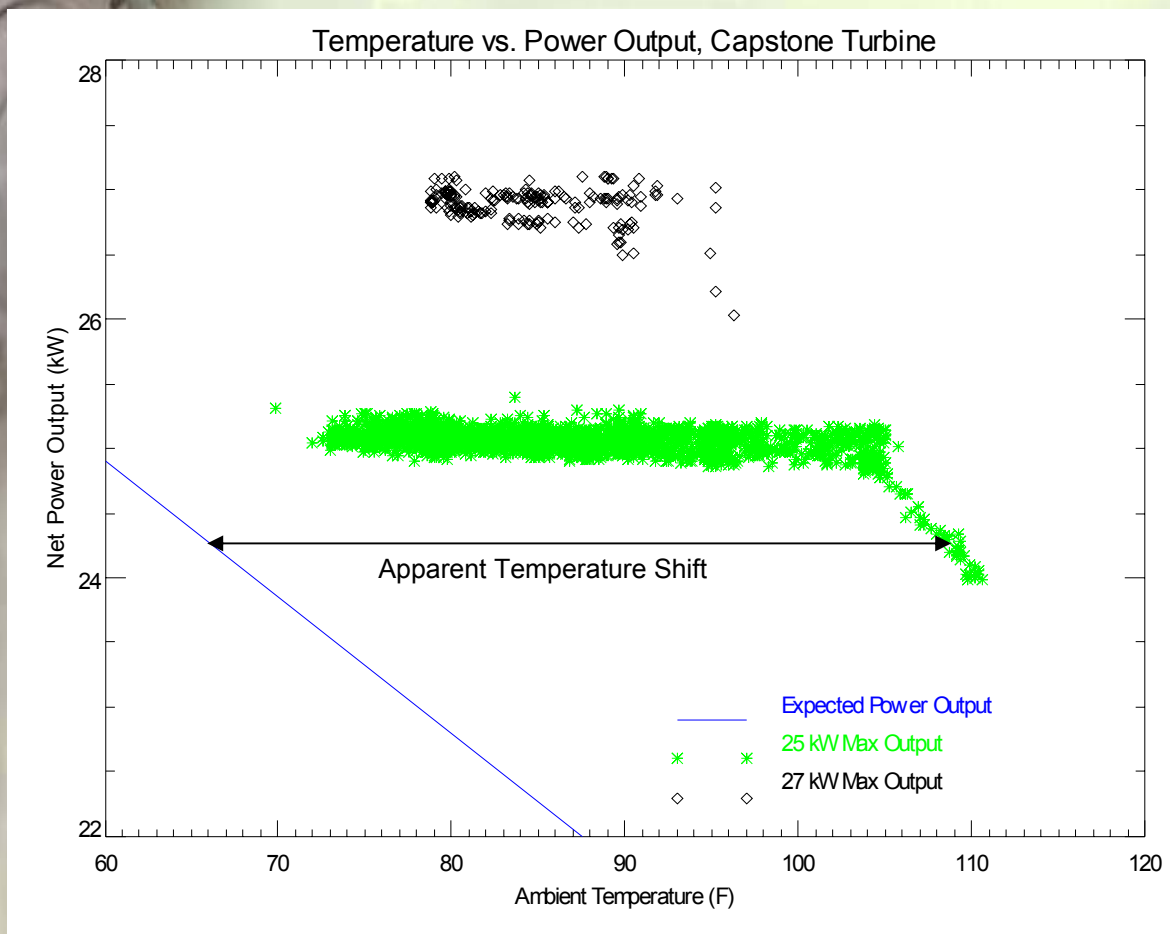


Figure 4. Trend of Measured and Expected Net Power Output with Ambient (all data)

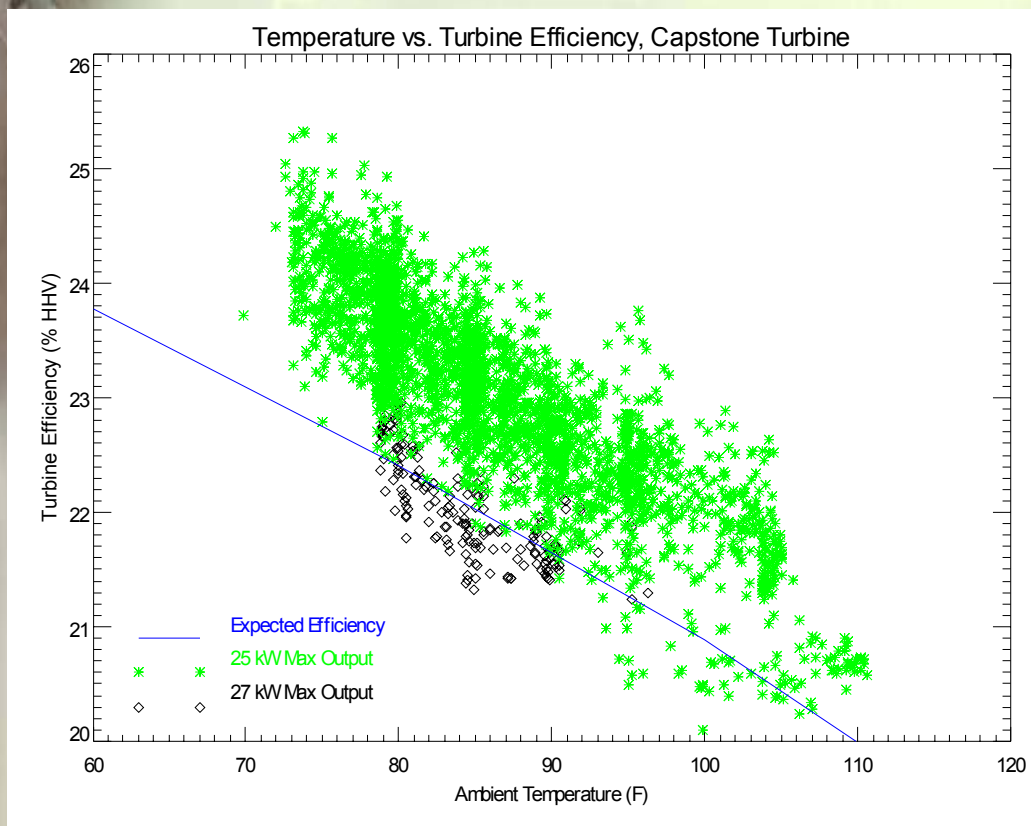


Figure 5. Trend of Measured and Expected Efficiency with Ambient

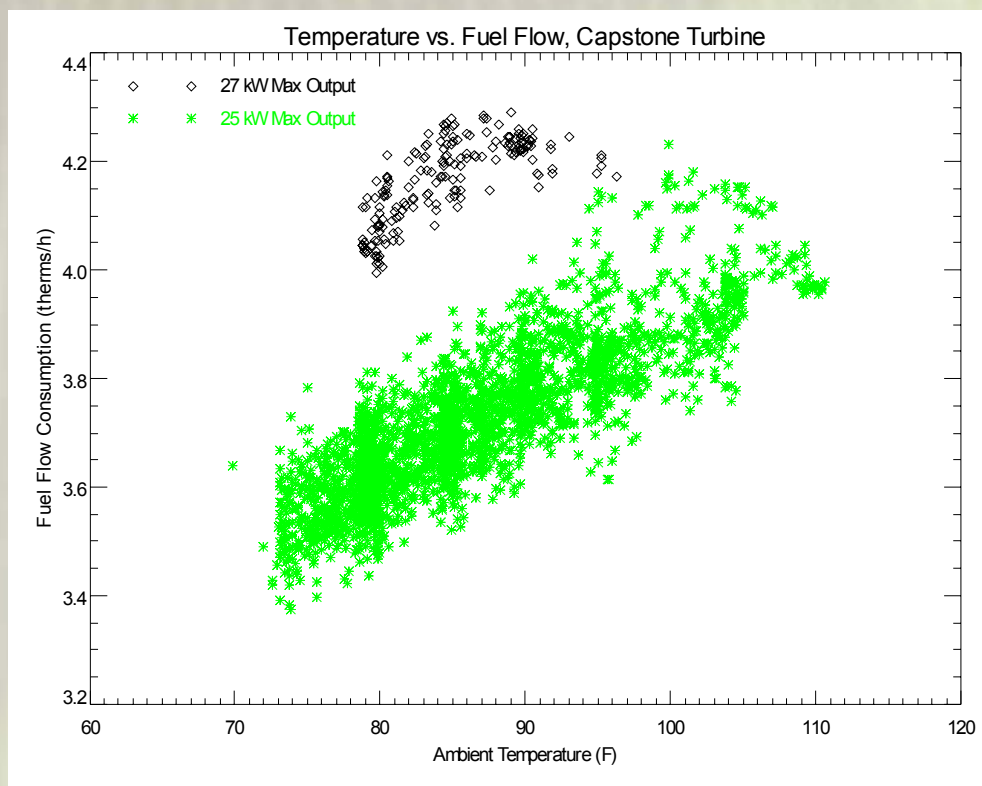


Figure 6. Trend of Measured and Expected Fuel Consumption with Ambient

Figures 7 and 8 below compare Capstone inlet temperature to the hourly weather data for the Portland Airport (Station 24229, obtained from the National Climatic Data Center (NCDC) weather database at www.ncdc.noaa.gov). Figure 7 compares the outside air temperature to the turbine inlet temperature when the turbine was running. Figure 8 compares the two values for a one-week period in December. The turbine inlet is consistently 35-40°F warmer than ambient. For a 6 day period in December (see Figure 7), the inlet temperature sensor was a locked at a constant value and appears to have malfunctioned. While it is possible that the mechanical room is slightly warmer than ambient, the turbine performance trends above imply that the room is probably not as warm as the sensor reading (since this puts the turbine performance well above expectations).

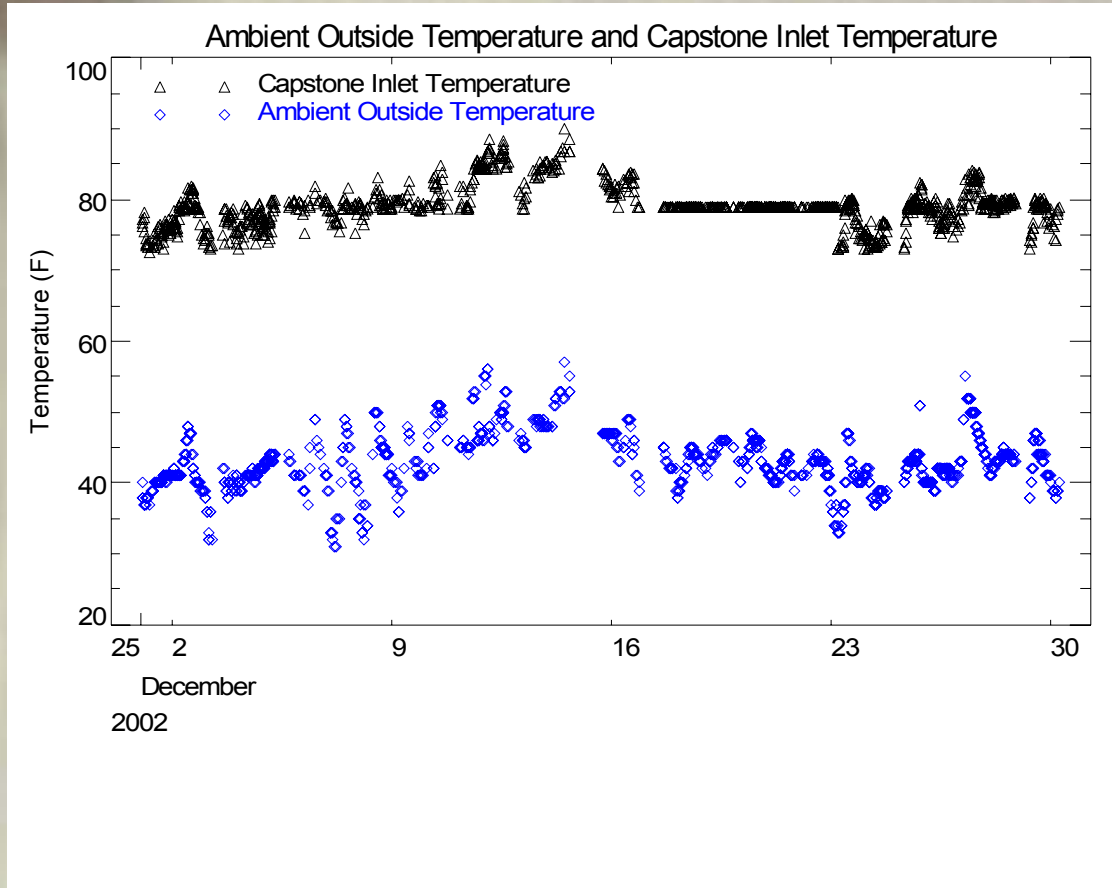


Figure 7. Comparing the Capstone Inlet Temperature to Local NCDC Readings (Portland Airport)

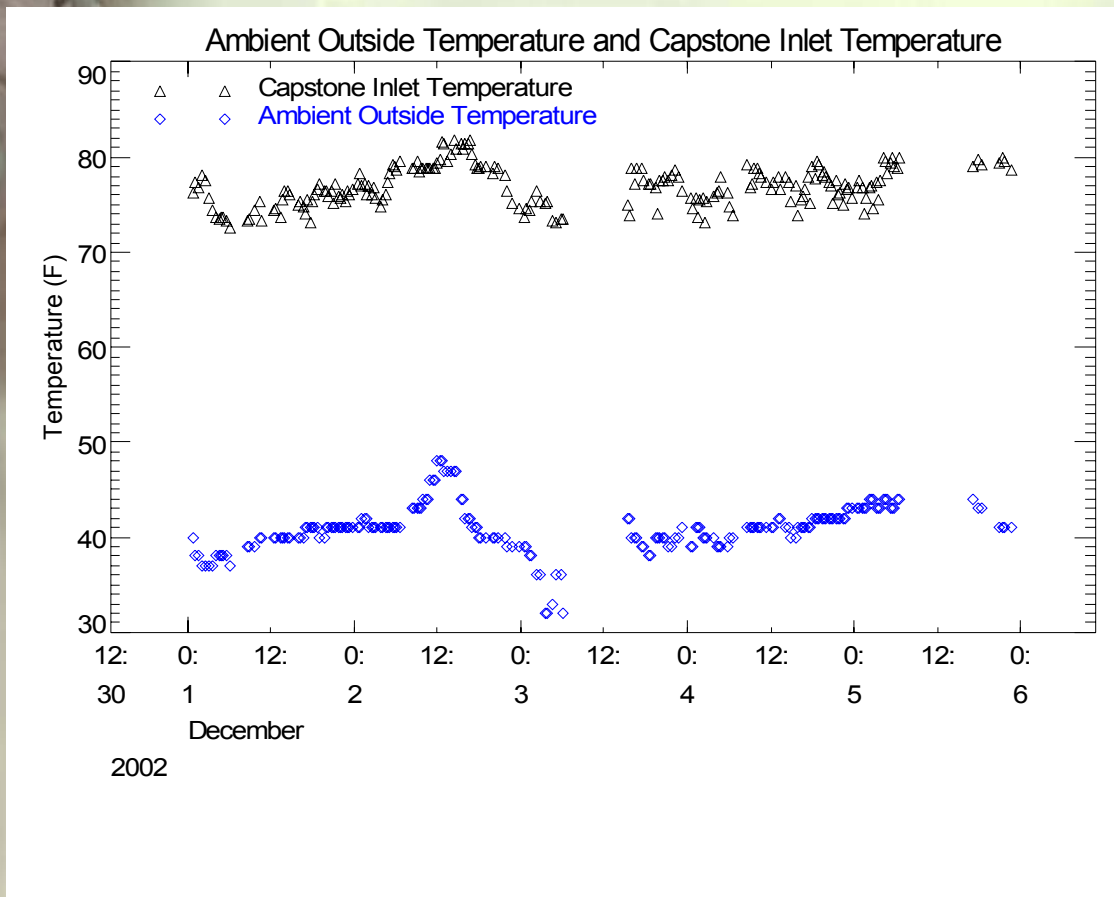


Figure 8. Comparing the Capstone and NCDG Readings for a One Week Period

Unifin Heat Exchanger

The Unifin heat exchanger (HX) transfers heat from the turbine exhaust to the hot water loop. Figure 9 shows that the hot water temperature rise across the HX was typically 10 to 15°F, providing between 150 to 200 MBtu/h of heat recovery. Figure 10 shows the temperatures and flow rates in the HX unit. The exhaust temperature is around 400°F and leaving exhaust temperatures from the HX unit are just above 200°F. The hot water flow rate was around 27 to 28 gpm for the beginning of the month. Figure 11 shows the heat rate against the expected trend. The measured values are lower than expected. These trends were consistent with the previous months of operation.

For about 1½ days starting December 3, the heat recovery flow rate suddenly jumped to 50 gpm and the hot water temperature rise correspondingly dropped to 6°F. The overall heat recovery rate remained about the same (as would be expected with the high entering exhaust temperatures on the other side of this heat exchanger).

Flow Meter Malfunctions

After December 16th, the hot water flow meter appears to malfunction. The hot flow rate drops to 7 gpm (as shown in Figure 10) yet the hot water temperature rise remained unchanged (Figure 10). This implies that the change in flowrate did not really happen but was an instrumentation issue. At approximately the same time, the chilled water flow rate jumped to 4 gpm (Figure 10). However, the chilled water temperatures also did not indicate any change in flow through the chiller at that time (i.e.,

these temperatures continued to float between 60-70°F, the average conditions in the mechanical room). Therefore, it appears that both the recorded flow readings are erroneous.

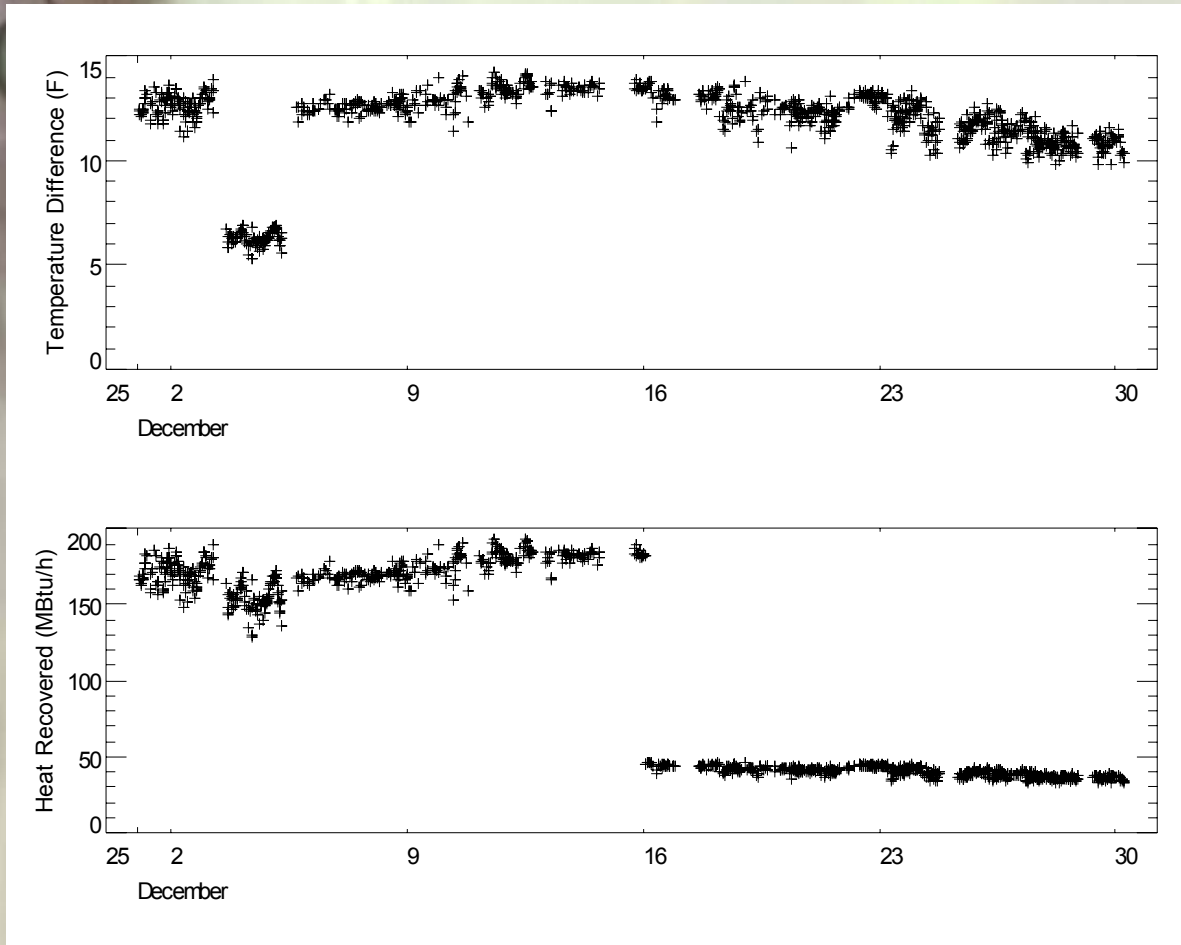


Figure 9. Unifin Delta-Temperature and Heat Recovery Rate

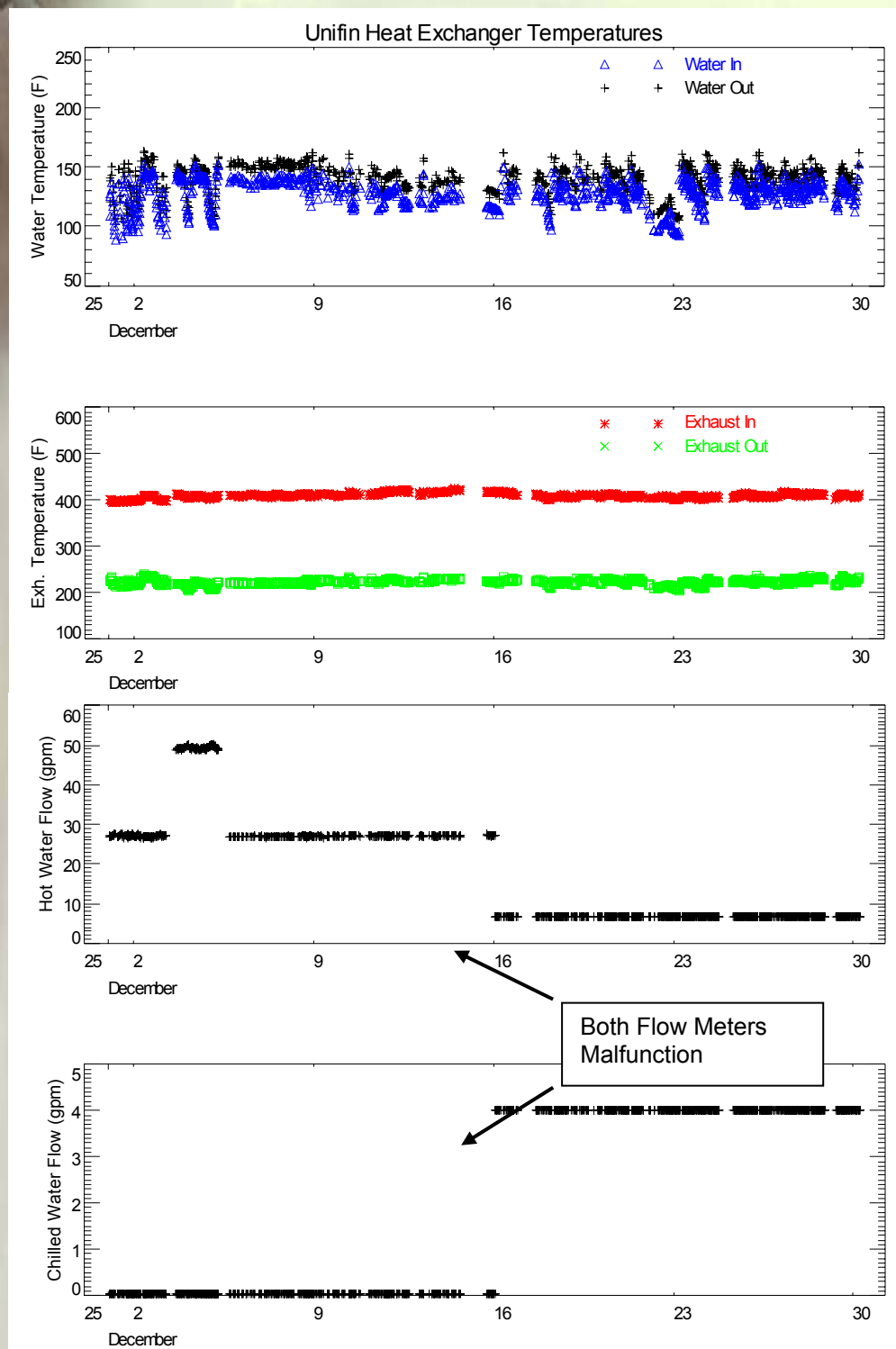


Figure 10. Unifin Exhaust and Water Temperatures Along with Hot Water Flow Rate

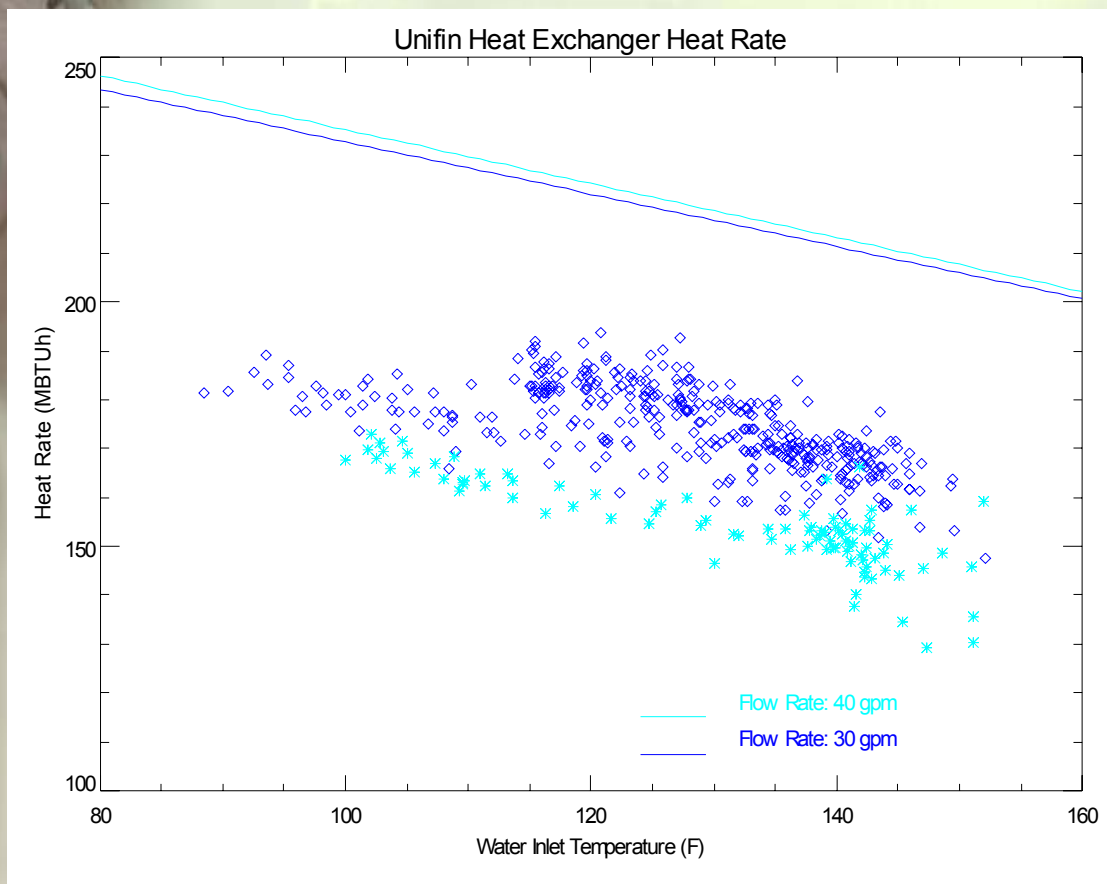


Figure 11. Unifin Heat Rate for Hot Water Flow around 30 and 40 gpm

Protective Relay Test

The Capstone microturbine protective relay was tested by an independent testing services company for grind interconnection compliance and met Bonneville Power's criteria.



30 KW Co-Generator Protective Relay Test Report

at
200 Market Street Facility
Portland, OR

for

EC Company
PO Box 10286
Portland, OR 97296

Attention: Mr. Alex Charlton
Order No: 89897-70520

eti Reference No. E001178 **Submitted By:** Dave Robbbaro
Senior Field Engineer


January 3, 2003 **Reviewed By:** 
Larry Newby
Region Manager

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1 PURPOSE

The new electrical equipment and components as defined in Section 3.0 of this report have been inspected and tested to help assure that each component meets manufacturer's and industry standards.

Evaluating the performance of new equipment prior to energization is considered the most important test the equipment ever receives. These tests often reveal hidden defects, design or installation errors, or in-transit damage, which can lead to serious system malfunction and down time.

This initial testing provides a database for future maintenance system analysis and equipment modification. These test results, when compared with the results from future periodic maintenance tests, can be indicative of life expectancy and thus provide a continuing monitor of reliability throughout the life of the equipment.

2 SUMMARY

This project was initiated by Mr. Alex Charlton with EC Company. All testing was performed by Electro-Test, Inc. (eti) Field Engineer Mr. Dave Robbbaro on Tuesday, December 3, 2002.

The protective relay package was found to be operational and acceptable service conditions. Please refer to Section 5, "Results and Recommendations," for complete details of the testing.

3 EQUIPMENT TESTED AND INSPECTED

- 3.1 One (1) Capstone Microturbine, 30 KW, protective relay, model # C30, SN # 002289.

4 PROCEDURES

4.1 Protective Relays

4.1.1 Electrical Tests

.1 Performed the following tests.

- Pickup parameters on each operating element.
- Timing functions.
- All testing was performed in accordance with the Capstone protective relay test manual # 410006-001, Rev A.

5 RESULTS AND RECOMMENDATIONS

The equipment listed in Section 3 was found to be operational and acceptable, as indicated by the attached field data sheet.

Please find a copy of the field data sheet and the Capstone Protective Test manual attached to the Appendix.



COMPLEX RELAY TEST DATA SHEET

CLIENT EC COMPANY	JOB NUMBER E001178	DATE 12/3/2002
LOCATION 200 MARKET ST.	FIELD ENGINEER D. Robbibaro	
RELAY NAMEPLATE DATA Capstone Turbine Corporation model #C30, SN# 002289. Software ver #4.76	TEST EQUIP. ASSET # F-2253, F2500	

COMPLEX RELAY TEST DATA

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	NOTES
	Test results	Secondary Pickup	120.00	119.7	120	98.1	97.8	98		n/a	n/a	n/a	n/a	n/a	n/a	60.48	59.28		
		Time test in sec.	1.9	1.89	1.9	1.9	1.89	1.9		0.028	0.036	0.028	0.092	0.100	0.09	0.117	0.1197		
	Set points	Pickup setting	524	524	524	428	428	428		n/a	n/a	n/a	n/a	n/a	n/a	60.5	59.3		
		Time setting in sec	1.9	1.9	1.9	1.9	1.9	1.9		0.032	0.032	0.032	0.095	0.095	0.095	0.09	0.09		
	Calculated system voltage	Vpu X 1.732 X KF See note 1)	527.91	526.59	527.91	431.6	430.2	431.1		in 1.69cy	in 2.19cy	in 1.69cy	in 5.50cy	in 6.01cy	in 5.51cy	in 7.04cy	in 7.18cy		
												BPA settings			Secondary Pickup		61.67		57.78
										Time in sec					0.092	7.490			
										Pickup setting					61.7	57.8			
										Time setting					0.100	7.50			

A Overvoltage phase A	E Undervoltage phase B	I Fast Overvoltage phase B, time test.	M Fast Undervoltage phase C, time test.
B Overvoltage phase B	F Undervoltage phase C	J Fast Overvoltage phase C, time test.	N Over Frequency, HZ
C Overvoltage phase C	G	K Fast Undervoltage phase A, time test.	O Under Frequency, HZ
D Undervoltage phase A	H Fast Overvoltage phase A, time test.	L Fast Undervoltage phase B, time test.	P

NOTES

1) KF = (277 V / 109 V = 2.54)

Test Objectives

Test and verify the unique attributes of dedicated power generation and core building cooling in the Pacific Northwest and document:

- Retrofit cost
- Energy savings
- Confirm thermal performance of the system components
- Potential integration improvements
- Replicability

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